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# Green IT: Case Studies

Chibli Joumaa, Seifedine Kadry*

*American University of the Middle East*

**Abstract**

In 2008, Murugesan [1] has defined Green computing or Green IT as the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems—such as monitors, printers, storage devices, networking and communications systems—efficiently and effectively with minimal or no impact on the environment. Recently, studies are being conducted to indentify the main pollutant components in IT systems. The aim is to try to reduce their pollution factor, maximize their energy efficiency during the product's lifetime and promote their recyclability. You may think that the 3% value on the product is a negligible value, however, Terawatts are being consumed by Information Technology systems: software, hardware and communication. Sooner or later the green computing will be an integral and important part of the wider green association. The goal of this article is to study the influence of the IT system components (hardware, software and some case studies) on the environment and how to use them resourcefully. Some recommendations will also be presented throughout the article.



Keywords: Green IT, Thin client, Green Bitorrent

## 1. Introduction

The concept of green computing goes back to 1992, when the U.S. environmental protection agency [7] launched the Energy Star program [8]. The Energy Star label was awarded to electronic products that succeeded in minimizing the use of energy while maximizing its efficiency. Energy Star was applied to different types of products like computer monitors, television sets and temperature control devices like refrigerators, air conditioners, and similar items. One of the first outcomes of green computing was the sleep mode option of computer monitors which places a consumer's electronic equipment on standby mode when a pre-set period of time passes and no user activity is detected. In parallel, the Swedish organization TCO Development (Tjänstemännens Centralorganisation) [9] launched the TCO Certification program to promote low magnetic and electrical emissions from CRT-based computer

* Corresponding author. Tel.: +965-66610985.
*E-mail address*: skadry@gmail.com.

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displays. As the concept developed, green computing began to encompass thin client solutions, energy cost accounting, virtualization practices, etc.

However, the electronic boom we have been witnessing throughout the last decades have caused a huge quantity of unwanted electronic products referred to as e-waste. E-waste has been increasing recently by 25-55 million tones every year. Greenpeace [10] claims that if the estimated amount of e-waste generated every year was put in a train, it will have a length as large as the earth's radius. This is a great threat to the environment due to the heavy metals (lead, mercury, cadmium, and beryllium) and other hazardous chemicals that are the main components of electronic devices.

Obviously, like any other electronic devices, computers require power. Currently the norm to generate power is still the coal power plants which is not environmentally-friendly or eco-friendly. In addition computer components often contain large amounts of lead and mercury. When inappropriately disposed, these toxic materials can leech into soil and water supplies. Newer components are manufactured to meet RoHs standards (Restriction of the use of certain Hazardous Substances). As of July 2006 this directive became a law, restricting the use of six substances in electrical and electronic equipment (EEE) sold within and to the European Union (EU) countries, hence the products will contain far less lead and mercury, and less toxic materials will be used to etch the electronic traces in the boards.

According to a report published by the Climate Group [11], a think-tank based in London, computers, printers, mobile phones and the widgets that accompany them, account for the emission of 830m tones of carbon dioxide around the world in 2010. That is about 2.2% of the estimated total of emissions from human activity. And that is the same as the aviation industry's contribution. According to the report, about a quarter of the emissions in question are generated by the manufacture of computers and so forth. The rest come from their use.

The same report estimates that the spread of computers will increase these associated emissions by about 6% a year until 2020, when one person in three will own a personal computer, half will have a mobile phone and one household in 20 will have a broadband internet connection. Yet computing can also be used to tackle climate change. For example, domestic consumption could be cut by the large-scale employment of smart meters in houses and flats. Households are the biggest users of electricity after manufacturing and transport. In Britain, they accounted for 29% of consumption in 2004, according to a government.

## 2. Computer Components and Resources

As stated above, the production of energy is a main cause of pollution. This is due to the use of fossil fuels; such as oil, coal and natural gas; which once burnt, generate the type of CO2 that we want to reduce. Moreover, the materials used for manufacturing burn some kind of fossil fuel as well. Fossil fuel consumption has increased over the last 60 years.

Studies from the Institute for Energy Research [12] showed that fossil fuels are the most abundantly produced resources in the United States, and electricity gets the lion's share of use. As a matter of fact, 50% of all the electricity used in the U.S. comes from burning coal, while it is a nonrenewable energy source (meaning, when it's gone, it's gone), and is dirty when it burns, it pumps CO2 into the air, adding to global warming, creating acid rain, and polluting water.

In this section, we will study in details the components of computer system: software and hardware and how to green each one by reducing their electricity usage, to minimize the CO2 production and pollution.

The basic question to start analyzing our carbon (electricity) footprint: how many laptops, computers, printers, scanners, sets of speakers, game consoles, and more are in your house/office? Also, take a closer look at when you bought those items and whether they're Energy Star certified (ENERGY STAR is a government-backed program helping businesses and individuals save energy and fight climate change [8]).

The next step is to find the average power consumption per each product. Table 1 shows general estimates of the average power consumption per each IT component.

Table 1. Average power consumption per IT component

| Component | Average power consumption (Watts) |
|---|---|
| Laptop | 22 |
| Desktop | 100 |
| Monitor | 50 – 150 |
| Router | 6 |
| Printer | 12 (inkjet) – 100 (laser) |
| Scanner | 3.5 – 21 |
| Digital camera | 26 |
| Speakers | 7 |

These numbers are general estimates. Products' energy consumption is related to the activity of the system. A computer or peripheral device in Sleep mode, for example, consumes less power than a printer pumping out a 20-page report.

The three biggest energy consumption components in the computer system are: the CPU (central processing unit or microprocessor that is the brain of the whole machine), the graphics card, and the monitor. Two others components may influence saving energy consumption: RAM and Printer.

## 3. Case Studies

### *3.1. The use of thin client instead of desktop PC*

In these times of economic uncertainty, businesses need to think about how to maximize profits—not just by increasing sales, but also by minimizing costs wherever possible. A major cost of running a business in the modern economy comes from supporting a business' information technology (IT) infrastructure. With thousands of computers, hundreds of servers, dozens of software applications, and the energy to power the computers and a fulltime IT staff to keep things running, businesses spend millions of dollars on IT each year. Probably the most well-known and expensive part of this infrastructure is the personal computer (PC).

The purpose of this case study is to quantify one such cost and how to reduce it by replacing, if possible, PC with thin client, which in turn reduces the pollution. Energy consumption is a major concern for businesses and the global population as a whole, and an important part of a bigger IT concern called total cost of ownership (TCO). One way to reduce TCO is to use server-based computing, a computing model in which applications run on a central back-end server and are displayed on desktop devices. A single server can support dozens of devices. Server based computing reduces TCO in several ways. It allows network administrators to maintain applications on a single server or small group of servers instead of on every desktop device. It allows access to application suites from any device connected to the server without having to install the applications on each individual device. Both PCs and thin clients can be used in a server-based computing environment; however thin clients are the preferred desktops for server-based computing.

Thin-client devices are simple computers designed to run applications from a central server. For example, both PCs and thin clients display the same commonly used Windows desktop interface to the end-user, and have the same features such as keyboard, mouse, serial and parallel ports and network connectivity. At the same time, thin clients are very different. They have lower microprocessor requirements and lower memory requirements than PCs while providing an identical end-user experience. Thin clients are literally smaller, some the size of a CD case, and most lack removable drives (or any drives), making it impossible for those using them to steal electronic data on floppy disk or introduce viruses to the network. There are many more benefits, but in short, thin-client devices are designed to cost less than PCs to run and maintain. Using thin client devices with server-based computing reduces TCO even more than server-based computing with PCs.

An additional factor makes thin-client devices even more attractive than PCs: they use significantly less power. In this case study, we compare a Wyse Winterm 3200LE Windows-based thin clients [15] (intended for those using office productivity applications) and desktop PC (1.5 GHz with 512MB RAM). The following table represents the power requirements for networks using thin client devices/PC with monitors:

Table 2. Power requirements for network using thin client devices/ PC with monitors

| Client device type | Single unit | 100 computers | 500 computers |
|---|---|---|---|
| 3200 | 90 Watts | 920 Watts | 460000 Watts |
| PC | 170 Watts | 17000 Watts | 850000 Watts |

We can use the following formula to compute the computer energy consumption:

$n \times p \times h \times 52$ = the number of kWh the computers uses each year, where n is the number of desktop/thin client devices, p is the power (in kilowatts) used by each device, h is the number of hours each week that the devices are turned on and 52 is the number of weeks in a year.

Multiply the result by the power costs in a given region, and businesses can see how a change in power consumption of desktop/thin client devices affects the amount of money spent each year on power. For example, assume that a network has 5,000 clients and those clients are on 50 hours a week. If these clients are PCs, then they’re using 2,210,000 kilowatt-hours each year. At 0.20 per kilowatt-hour, that comes to $442,000 to power the devices each year. Make those devices the Wyse Winterm 3200LE, and the numbers drop significantly: those 5,000 devices use 460,000 kilowatts each year for an annual cost of $92,000—one-fourth the cost of powering the PCs. It is possible to lower the power consumption costs of computing environments through the use of desktop monitors that consume less power; however the cost savings are minimal in comparison to changing from a PC to a thin-client environment. Based on this result, it is clear that thin-client devices are more energy-efficient than personal computers, with some models using 85 percent less power than their PC rivals in real world environments. This energy efficiency translates into significant, measurable cost savings for businesses both in the short and the long term.

### *3.2. The energy consumption in Torrent systems with malicious content*

BitTorrent implements an unstructured overlay network customized for file sharing. In the BitTorrent terminology nodes of the overlay are called peers and the collection of peers involved in the distribution of a given file is called a torrent or swarm. The basic idea of BitTorrent is that peers both download and upload (equal-size) chunks of the shared files. This results in the fact that each peer downloads a given file from a multitude of other peers, instead of downloading it from a single server as in a conventional client-server model. The resulting capacity of such cooperative downloading process is higher than that of the traditional client-server architectures [5]. As shown in Figure 1, a tagged peer wishing to download a file from scratch needs to get a corresponding torrent file - hereafter referred to as torrent – from the system. Torrents are very small files, typically hosted by conventional Web servers (torrent servers), and can be found through standard Internet search engines. A torrent contains the name of the file's tracker. This is a node that constantly tracks which peers have chunks of the file (i.e., belong to the swarm). When a peer joins a swarm it registers with the tracker and, then, periodically informs the tracker that it is still in the swarm.

Once obtained the tracker's address, the tagged peer opens a TCP/IP connection to the tracker and receives a random list of peers to be contacted for starting the download process. At any given time the tagged peer will be in touch with a set of peers, called neighbors, with which it exchanges parts of the file. The neighbor set changes dynamically since, as time elapses, some peers may leave the swarm and others may join. In addition, each peer preferentially selects, for downloading chunks, those peers from which it can achieve the highest download rate. Furthermore, every 30 seconds neighbors are selected completely at random, as a way to discover new neighbors and allow new peers in a swarm to start-up.

This legacy BitTorrent architecture is not energy efficient. BitTorrent peers have to stay connected to the overlay network during the whole download process of requested files, which, typically, may take several hours. Periodically turning off peers without modifying the BitTorrent architecture is not a viable solution for several reasons. First of all, if a peer is downloading content, powering it off does not save any energy (related to the current download), as the download itself stops when the peer turns off. Also, powering off peers that are not downloading anything (but are sharing content) is also not an efficient solution in general, as this can result in decreasing the overall download performance of the swarms they are part of. Thinking of coordinated ways for powering those peers is also not appropriate, as it would require central control, and is thus at odds with the BitTorrent P2P design paradigm.The authors in [5] proposed a proxy-based Energy Efficient BitTorrent (EE-BT) architecture to overcome these drawbacks. The basic idea of this architecture is illustrated in Figure 2.

It assumes a standard LAN environment where a certain number of users run BitTorrent peers on their PCs. One computer in the LAN behaves as a proxy between the peers and the rest of the BitTorrent network. The proxy can either be a dedicated computer, or a machine that has to be continuously powered on for providing other network services (e.g., DHCP, Web proxy, etc.). Clearly, the latter case is preferable from an energy saving standpoint. Peers "behind" the BitTorrent proxy ask the proxy itself to download the requested content on behalf of them. The proxy participates to the conventional BitTorrent overlay, and takes care of all downloads of the peers behind it.

While downloads are in progress, the peers behind the proxy can be switched off without stopping the requested downloads. Finally, the requested files are transferred from the proxy to the peers upon completion. The proposed architecture is evaluated in a realistic testbed, measuring the file download time with the legacy and proxy-based architectures, respectively. The experimental results have shown that the proxy-based architecture can save up to 95% of the energy consumed by each PC when using the legacy solution. This shows the effectiveness of the approach from the energy efficiency point of view. In addition, the results have shown that using the BitTorrent Proxy does not introduce any degradation to the QoS. Rather, the average time to download a file reduces by approximately 22% when using the proxy-based architecture since the number of files shared with the overlay network by the proxy is greater than the number of files shared by any single peer. Therefore, this architecture is also scalable, as it does not require modifications of the BitTorrent global architecture, nor global coordination between sets of BitTorrent peers

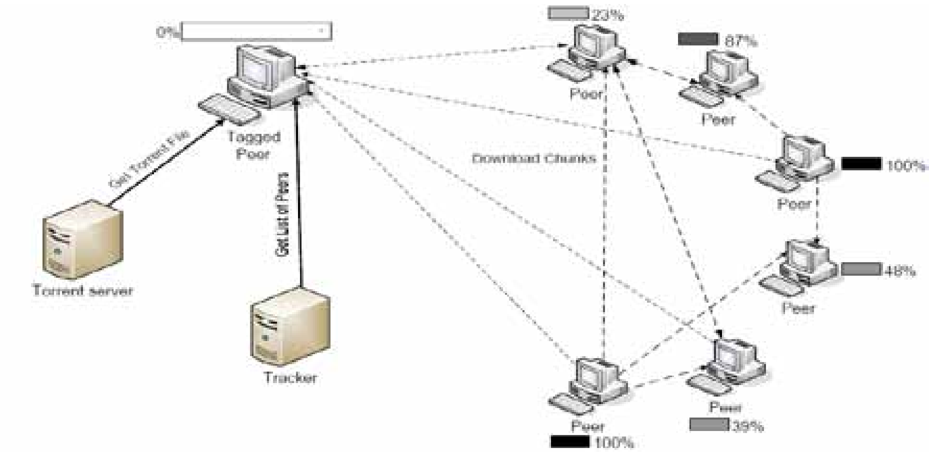
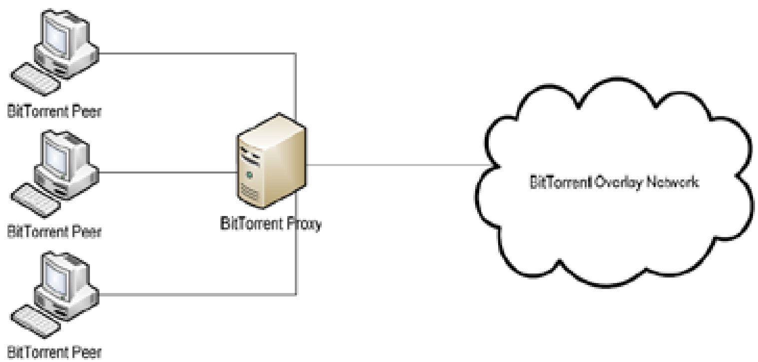



Fig. 1. File distributions process. The figure gives a snapshot of the system at the time when the tagged peer starts the download process.




F ig 2. High level representation f the Energy-Efficient Bit Torrent architecture

## 4. Conclusion

As stated throughout the document, green computing is one of the major fields of research nowadays. As a matter of fact, with the huge increase of IT technologies and their catastrophic impact on the environment, many standards came to life to make the IT system components greener. In this paper, we focused on the consumption of energy by computers. We presented two case studies that help in a greener computing. In the first case study, we proved that using thin clients instead of PC results in huge savings in terms of energy consumption. In the second case, we proposed a proxy-based Energy Efficient BitTorrent architecture that can enhance energy savings without affecting the QoS.

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